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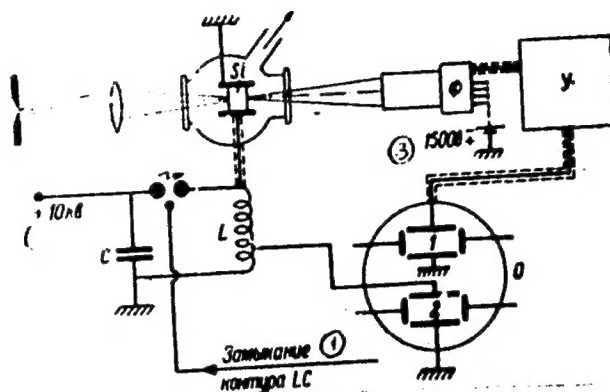
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2111/E102

Effect of a high- electric

ASSOCIATION: P. I. Lebedev AN SSSR, Moskva  
(Institute of Physics)

P. I. Lebedev AN SSSR, Moskva  
P. I. Lebedev AS USSR, Moscow)

SUBMITTED: April



Card 3/4

30769  
S/181/61/003/011/001/056  
B102/B138

26.2421

AUTHORS:

Plotnikov, A. F., Vavilov, V. S., and Smirnov, L. S.

TITLE:

Kinetics of photoconductivity in p-type neutron-irradiated silicon

PERIODICAL: Fizika tverdogo tela, v. 3, no. 11, 1961, 3253 - 3259

TEXT: The defect formation due to fast-neutron irradiation was investigated in single crystals of p-type silicon. The specimens used had been described by the authors in an earlier paper (FTT, 3, 8, 1961). The defect level system arising due to the fast-neutron irradiation in the forbidden band is shown in Fig. 1. The photoconductivity investigated was that connected with the electron transitions to the levels  $E_v + 0.30$  ev,

$E_v + 0.38$  ev and  $E_v + 0.45$  ev. Temperature was around  $100^\circ\text{K}$ . The electron was excited by steep-sided light pulses with rise and decay times of 5  $\mu\text{sec}$  each. Photoconduction relaxation was studied separately for each level by two independent methods.  $E_v + 0.30$  ev: (1) The build-up time  $\Delta p_{bn}$  of photoconductivity was found at  $\Delta p \sim p_0$  on an ЭХО-1 (ENO-1) oscilloscope. X  
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Kinetics of photoconductivity in ...

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B102/B138

$m_0$ , the initial electron concentration at level M, was found to be  $\approx 8 \cdot 10^{12} \text{ cm}^{-3}$  and  $\sigma_p \approx 3 \cdot 10^{-14} \text{ cm}^2$  was determined for the hole trapping cross section. (2) The build-up curves  $\Delta p_m = f(t)$  were investigated for  $p_0 \gg \Delta p$ . It was confirmed that the building is governed by an exponential law. The parameters of the centers were found to be  $m_0 \approx 10^{13} \text{ cm}^{-3}$ ,  $\sigma_p \approx 3 \cdot 10^{-14} \text{ cm}^2$  (first illumination) and  $m_0 \approx 10^{13} \text{ cm}^{-3}$ ,  $\sigma_p \approx 2.5 \cdot 10^{-14} \text{ cm}^2$  (second illumination).  $E_v + 0.38 \text{ eV}$ : (1) Recording of the relaxation pulses without constant illumination for  $p_0 \approx 8 \cdot 10^8 \text{ cm}^{-3}$  and  $\Delta p \approx 3 \cdot 10^8 \text{ cm}^{-3}$  yielded:  $m_0 q I \sim 10^9 \text{ cm}^{-3} \cdot \text{sec}^{-1}$  and  $\sigma_p \approx 5 \cdot 10^{-17} \text{ cm}^2$ . (2) Recording of  $\Delta p_m$  with constant illumination ( $p_0 \approx 6 \cdot 10^8 \text{ cm}^{-3}$  and  $\Delta p \approx 3 \cdot 10^8 \text{ cm}^{-3}$ ) yielded:  $m_0 q I \sim 10^9 \text{ cm}^{-3} \cdot \text{sec}^{-1}$  and  $\sigma_p \approx 7 \cdot 10^{-17} \text{ cm}^2$ . ( $q$  - capture cross section of a photon by an electron at the level M;  $I$  - intensity of exciting light.)  $E_v + 0.45 \text{ eV}$ :  $\Delta p_{bn}$  was studied as a function of time. It was found that for  $t < 0.2 \text{ sec}$  carriers localized at centers with  $E_v + 0.30 \text{ eV}$  X  
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Kinetics of photoconductivity in ...

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B102/B138

and for  $0.2 < t < 0.6$  sec carriers localized at  $E_v + 0.38$  ev participated in relaxation. For  $t > 0.6$  sec the carriers taking part in relaxation were localized in centers with the following parameters:  
 $\sigma_p \approx 10^{-17} \text{ cm}^2$  and  $m_0 q I = 10^9 \text{ cm}^{-3} \text{ sec}^{-1}$ ; they belong to the  $(E_v + 0.45 \text{ ev})$  level. Finally the relaxation of photoconductivity was studied which was connected with electron transitions from the valence band to the  $(E_v - 0.16 \text{ ev})$  level. This level was found to be an effective electron trap, with a cross section of  $\sigma_n \sim 10^{-13} - 10^{-15} \text{ cm}^2$ . For holes the trapping cross section was only  $\sim 10^{-19} \text{ cm}^2$ . Result: Exposure of high-purity p-type silicon specimens (resistivity  $\rho \sim 110 \text{ ohm}\cdot\text{cm}$ ; oxygen content:  $\sim 5 \cdot 10^{15} \text{ cm}^{-3}$ ; hole concentration in the dark:  $8 \cdot 10^8 \text{ cm}^{-3}$ ; Fermi level:  $0.2 - 0.3 \text{ ev}$  distant from the edge of the valence band) to a fast-neutron flux ( $\sim 10^{13} \text{ n/cm}^2$ ) with  $\sim 1 \text{ Mev}$  led to the appearance of  $\sim 10^{14} \text{ defects/cm}^3$  in the forbidden band. The authors thank B. M. Vul, S. M. Ryvkin, L. D. Paritskiy, I. D. Yaroshetskiy, G. N. Galkin and B. S. Kopylovskiy  
Card 3/4

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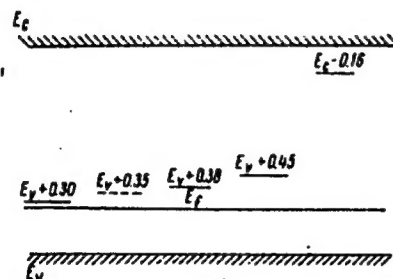
Kinetics of photoconductivity in ...

for remarks, critics and help. There are 10 figures and 5 references:  
4 Soviet and 1 non-Soviet.

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR Moskva  
(Physics Institute imeni P. N. Lebedev AS USSR, Moscow)

SUBMITTED: April 29, 1961

Fig. 1



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*[Handwritten mark]*

24,7700 (1144, 1385, 1559)

29301  
S/053/61/075/002/004/007  
B125/B102

AUTHOR: Vavilov, V. S.

TITLE: Processes of radiation ionization in germanium and silicon crystals

PERIODICAL: Uspekhi fizicheskikh nauk, v. 75, no. 2, 1961, 263 - 276

TEXT: The author restricted his investigation to photoionization and ionization under the action of charged particles, when valence electrons are liberated in semiconductor crystals. Ionization of impurity atoms as well as thermal and impact ionization in a strong electric field were left unconsidered. The experimental arrangement is illustrated in Fig. 1. Measurements made on silicon single crystals confirmed theoretical predictions concerning the effect of an external electric field upon photoionization. In the spectral region corresponding to valence band - conduction band transitions, the edge of the absorption band is shifted considerably. In case of 0.8 - 0.9  $\mu$  wavelengths, the field applied raises the absorption coefficient strongly. This phenomenon is a true "field effect", and is not associated with carrier absorption. B. M. Vul, L. V. Keldysh (ZhETF 34, 1138 (1958)), F. F. Vol'kenshteyn (Trudy FIAN 1, 123 (1937)), and K. I. Britsyn are mentioned in this connection. The

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B125/B102

Processes of radiation...

quantum yield of photoionization in crystals with p-n junctions is determined along with the spectral dependence of the quantum yield of photoionization in germanium crystals. This investigation of photoionization inside the main optical absorption band of germanium and silicon showed that the quantum yield exceeds unity by far if the photon energies are sufficiently high. M. N. Alentsev, S. I. Vavilov (Sobr. soch., t. 2, M., Izd-vo AN SSSR, 1952, str. 293), F. A. Butayeva, V. A. Fabrikant (Izv. AN SSSR, ser. fiz. 21, 541 (1957), S. Koc, Českoslov. časopis pro fiziku, 6, 668 (1956)), E. Antonchik, Českoslov. časopis pro fiziku, 7, 651 (1957) are mentioned in this connection. If the photon energies are a multiple of the forbidden band width (as with X-radiation and  $\gamma$ -rays), the quantum yield will be proportional to the photon energy:  $\eta = h\nu/\epsilon$ . M. V. Chukichev, and V. S. Vavilov (Fiz. tv. tela, 3, 935 (1961)) found  $\epsilon = 2.5 \pm 0.3$  ev in their study of ionization in germanium single crystals that were gamma-irradiated by a  $\text{Co}^{60}$  source. The same had been found by the Czechoslovakian physicists Dragokupil, Malkovskaya, and Tauts (Cs. J. Phys. 7, 521 (1957)). In case of ionization in germanium and silicon crystals under the action of fast charged particles, the energy per electron-hole pair does not depend upon the particle energy. V. S. Vavilov, L. S. Smirnov, V. M. Patskevich

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29301

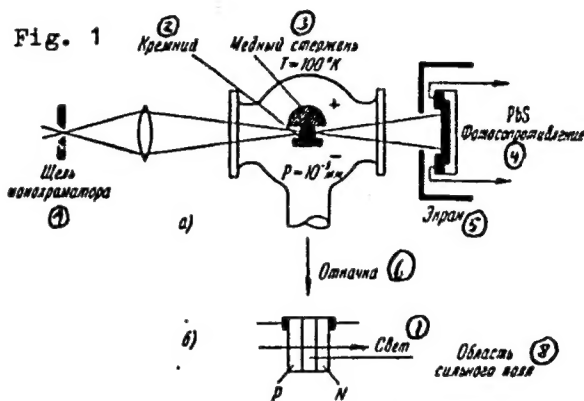
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B125/B102

Processes of radiation...

(DAN SSSR 112, 1020 (1957)) are mentioned. There are 11 figures and 30 references: 23 Soviet-bloc and 7 non-Soviet-bloc. The three most recent references to English-language publications read as follows: A. Plann, W. Van Roosbroeck, J. Appl. Phys. 25, 1422 (1954); K. MacKay, Phys. Rev. 108, 29 (1957); P. Wolfe, Phys. Rev. 95, 1415 (1954).

Fig. 1. Experimental arrangement.

Legend: (1) Monochromator slit, (2) silicon, (3) copper rod, (4) PbS photoresistor, (5) shield, (6) evacuation, (7) light, (8) strong-field region.



Card 3/3

VAVILOV, V. S.; SMIRNOVA, I. V.; CHAPNIN, V. A.

"On Defects Introduced by Fast Electrons into Silicon Doped by Lithium"

Paper was submitted at the International Conference on  
Crystal Lattice Defects at Kyoto, 7-12 Sep '62

(for Vavilov, v. s.) P. N. Lebedev Inst. of Physics  
Leninsky, Prospect 53, Moscow

24.3300

39169  
S/120/62/000/003/042/048  
E032/E114

AUTHORS: Plotnikov, A.F., Vavilov, V.S. and Kopylovskiy, B.D.

TITLE: An apparatus for studying the spectra and kinetics of photoconductivity in semiconducting crystals

PERIODICAL: Priory i tekhnika eksperimenta, no.3, 1962, 183-187

TEXT: The apparatus was designed for studying photoconductivity in single crystals in the infrared part of the spectrum at low temperatures. A block diagram of the apparatus is shown in Fig.1. The infrared radiation is taken from an MKC-12 (IKS-12) monochromator and is focused on the specimen by a system of mirrors. The radiation reaching the specimen is partly reflected on to a bolometer  $\bar{B}$  whose output is fed into an amplifier tuned to 9 c.p.s. This is used to control the incident intensity. The specimen is placed in a conventional metal cryostat and maintained at  $-100^{\circ}\text{K}$ . Thick germanium and silicon filters  $\bar{C}$  are used to reduce scattered radiation. The specimen is connected by short leads to the input stage of an amplifier, which is in the form of a cathode follower with double screening and negligible grid current. The double screening

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An apparatus for studying the spectra... S/120/62/000/003/042/048  
E032/E114

ensures low input capacitance. The input stage is connected to a narrow-band amplifier tuned to 9 c.p.s. which is followed by a synchronous detector coupled to the modulator. The sensitivity is  $0.5 \times 10^{-8}$  V/division with an input resistor of  $5 \times 10^{13}$  ohm. The photoconductivity spectrum and the incident spectrum are recorded on a pen recorder chart. Both a.c. and d.c. operation is possible. Amplifier circuit diagrams are reproduced. The apparatus has been used to measure photoconductivity spectra of fast neutron-irradiated silicon crystals. An account of the results is given elsewhere (V.S. Vavilov, A.F. Plotnikov, J.Phys.Chem. Solids, Pergamon Press, 22, 1961, 31). Studies of the kinetics of impurity photoconductivity carried out with this apparatus have led to a determination of the cross-section for carrier capture by levels associated with structural defects which are produced in p-silicon after irradiation by fast neutrons.

There are 6 figures.

ASSOCIATION: Fizicheskii institut AN SSSR  
(Physics Institute AS USSR)

Card 2/8  
SUBMITTED: October 6, 1961

37925  
S/181/62/004/005/009/055  
B102/B138

247700

AUTHORS: Vavilov, V. S., Smirnova, I. V., Chapnin, V. A.

TITLE: The interaction of lithium atoms introduced into silicon with the radiation defects of the structure

PERIODICAL: Fizika tverdogo tela, v. 4, no. 5, 1962, 1128-1131

TEXT: The authors studied the interaction of Li impurity atoms in Si single crystals with the structural defects that were produced by fast-electron bombardment. The Li impurity was introduced by diffusion from a Sn-Li melt containing 0.2 - 1% Li. Li equilibrium concentration in Si was reached at 550-650°C. The Li samples were p-type ( $\rho \sim 150 \text{ ohm}\cdot\text{cm}$ ) and cut out of single crystals. After introduction of Li the p-type samples were transformed to n-type with carrier concentrations of  $3 \cdot 10^{14} - 10^{16} \text{ cm}^{-3}$ . Since Li formed oxide ions  $\text{LiO}^+$ , which have shallow donor levels and are relatively stable at room temperature, the carrier concentration (n) equals the sum of the ions  $\text{Li}^+ + \text{LiO}^+$ . Electron bombardment (0.9 Mev) took place at room temperature. At Li concentrations

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The interaction of lithium atoms ...

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of  $3 \cdot 10^{14} - 5 \cdot 10^{15} \text{ cm}^{-3}$  two level groups were found in the upper half of the forbidden band:  $E_c = 0.17$  and  $0.4$  eV. For the level  $E_b$  which is filled with electrons  $E_b = 0.17$  eV is found. When the irradiated samples are heated to  $330-350^\circ \text{K}$  the carrier concentration was found to be greatly reduced. The results, presented by a curve, which has three sections, can be described by

$$\frac{n}{n_0} = A e^{-\frac{t}{\tau_1}} + B e^{-\frac{t}{\tau_2}} + C e^{-\frac{t}{\tau_3}}, \quad (1).$$

$$\tau_1 < \tau_2 < \tau_3.$$

The effective diffusion coefficient  $D_{\text{eff}} = 0.1\% D_0$ ,  $D_0$  is the diffusion coefficient of Li when C is absent. There are 2 figures.

ASSOCIATION: Moskovskiy gosudarstvennyy universitet im. M. V. Lomonosova (Moscow State University imeni M. V. Lomonosov)

SUBMITTED: December 8, 1961

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S/181/62/004/005/050/055  
B163/B138

AUTHORS: Malovetskaya, V. M., Galkin, G. N., and Vavilov, V. S.

TITLE: The spectrum of radiation defects in silicon

PERIODICAL: Fizika tverdogo tela, v. 4, no. 5, 1962, 1372-1374

TEXT: After electron irradiation of silicon local energy levels are found in the forbidden band at 0.17 eV and 0.4 eV below the conduction band (acceptor levels) and 0.27 eV above the valence band (donor level). While the two acceptor levels have been shown to correspond to an association of a vacancy with oxygen and phosphorus respectively, the nature of the donor level remained unknown. p-type silicon crystals with varying oxygen content were drawn from quartz crucibles and irradiated with 1 MeV electrons from an electrostatic generator at  $17 \pm 1^\circ\text{C}$ . The oxygen concentration was determined from the intensity of the infrared absorption band at 9.1 microns. The position of the energy levels and the defect concentration were determined from the temperature dependence of the charge carrier concentration measured by the Hall effect. This is better than measuring resistivity or life-time at constant temperature, as the latter give less precise

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B163/B138

The spectrum of radiation ...

information on the respective influence of different simultaneously existing defects. In silicon specimens drawn from quartz crucibles with an oxygen concentration of  $(2-3) \cdot 10^{17} \text{ cm}^{-3}$ , a donor level was found 0.27 ev above the valence band. It was rather stable and could only be annealed above  $300^\circ\text{C}$ . p-type silicon produced by zone melting in vacuum without a crucible with an oxygen concentration of about  $5 \cdot 10^{15} \text{ cm}^{-3}$  showed mainly other defects at levels of  $0.21 \pm 0.01$  ev above the valence band. This was determined from the position of the Fermi level when half of the defect levels were occupied. The 0.21 ev defects were much less stable than the 0.27 ev ones, and annealing was noticeable at room temperature. The temperature dependence of the hole concentration was measured between 125 and  $400^\circ\text{C}$  for specimens annealed between 17 and  $120^\circ\text{C}$ , and from this the annealing activation energy was found to be  $0.72 \pm 0.04$  ev. The 0.27 ev defects may be due to interaction between oxygen with interstitial atoms. The much slower rate of formation of the +0.27 ev defects as compared with the -0.17 ev defects is attributed to the fact that interstitial atoms have less mobility than vacancies. 0.21 ev defects were also found in A. F. Plotnikov's investigations on the spectra of stationary photoconductivity. There is a figure.

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S/181/62/004/005/050/055  
B163/B138

The spectrum of radiation ...

ASSOCIATION: Fizicheskij institut im. P. N. Lebedeva AN SSSR, Moscow  
(Physical Institute imeni P. N. Lebedev AS USSR, Moscow)

SUBMITTED: February 5, 1962

Card 3/3

37949

S/161/62/004/005/051/055  
B163/B138

240700

AUTHORS: Nolle, E. L., Malovetskaya, V. M., and Vavilov, V. S.

TITLE: The effect of oxygen on the life-time of minority carriers in p-type silicon

PERIODICAL: Fizika tverdogo tela, v. 4, no. 5, 1962, 1374-1376

TEXT: Single crystals of p-type silicon were obtained by zone melting without a crucible. Very low oxygen content was achieved by zone refinement in a hydrogen atmosphere or in vacuum. In the top part of the single crystal the oxygen concentration was increased by making part of the last passage in an atmosphere of moist hydrogen. The oxygen concentration was determined from the intensity of the infrared absorption band at 9.1 microns. The life-time was measured by B. D. Kopylovskiy's phase method at a low injection level. With oxygen content increasing from  $5 \cdot 10^{16} \text{ cm}^{-3}$  to  $1.5 \cdot 10^{17} \text{ cm}^{-3}$  the carrier life-time increases from 1.6 to 32 microseconds. Its temperature dependence was measured between 220 and 450°K and was found to diminish with temperature. The decrease is less for specimens with higher oxygen concentrations, and below 0°C, it increased

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B163/B138

The effect of oxygen on the ...

again, indicating the existence of trap levels. Below 0°C the life-time was reduced by biaslighting, and increased above. The temperature dependence of life-time in specimens with low oxygen content followed the dependence calculated for a recombination level with an activation energy of 0.27 ev. The temperature dependence of life-time for a specimen with an oxygen concentration of  $1.5 \cdot 10^{17} \text{ cm}^{-3}$  cannot be described by the statistical theory of Shockley and Read for one recombination level. The tremendous increase with rising oxygen concentration must be due to the interaction of oxygen with impurity atoms, dislocations and defects of the vacancy - interstitial type, to form recombination centers in silicon. It appears that the resulting recombination centers have small cross sections for the capture of minority carriers. There are 2 figures.

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR, Moscow  
(Physical Institute imeni P. N. Lebedev, AS USSR, Moscow)

SUBMITTED: February 5, 1962

Card 2/2

39251  
S/181/62/004/007/033/037  
B111/B104

26.2420  
AUTHORS:

Vavilov, V. S., Galkin, G. N., Malovetskaya, V. M., and  
Plotnikov, A. F.

TITLE:

Photo and thermoionization energies of deep level  
radiation defects in Si

PERIODICAL:

Fizika tverdogo tela, v. 4, no. 7, 1962, 1969-1970

TEXT: Experimental results of thermal and photoionization are compared  
by utilizing a fact recently discovered in the annealing of p-type Si,  
namely that the difference in stability of two closely adjacent levels of  
the centers resulting from 1 Mev electron bombardment amounts to  
 $E_v + 0.21$  ev. Fig. 1 shows that the raising of the level balances the  
disappearance of charge carriers (holes) on the donor level ( $E_v + 0.19$  ev).  
This defect is stable even at 200°C. There are 2 figures and 1 table.

ASSOCIATION:

Fizicheskiy institut im. P. N. Lebedeva AN SSSR Moskva  
(Physics Institute imeni P. N. Lebedev AS USSR Moscow)

24.7700,

S/181/62/004/009/015/045  
B108/B186

AUTHORS: Gippius, A. A., and Vavilov, V. S.

TITLE: Radiative recombination on dislocations in germanium

PERIODICAL: Fizika tverdogo tela, v. 4, no. 9, 1962, 2426 - 2433

TEXT: A mirror monochromator and a lead sulfide photoresistor were used to investigate the radiative recombination in Ge crystals whose dislocation density ranged from  $5 \cdot 10^3$  to  $1 \cdot 10^4 \text{ cm}^{-2}$  and whose electron equilibrium concentrations varied between  $5 \cdot 10^{13}$  and about  $10^{16} \text{ cm}^{-3}$ . At nitrogen temperatures, an intrinsic band was established at  $1.71 \mu$ , due to indirect band-to-band transitions. Another band, established at  $2 - 2.5 \mu$  occurs only in crystals which have dislocations and are the result of carrier transitions between local levels. It is better resolved in the case of high electron concentrations and it shows recombination levels at a distance of 0.22 and 0.14 eV from the conduction band. Probably another level or level group exists at a distance of about 0.18 eV from the conduction band. The half-width of the emission line related to the

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B108/B186

Radiative recombination...

transition of holes to one of the levels equals 0.016 ev. The intensity of the intrinsic band is proportional to  $I^m$  ( $I$  is the injection current,  $m \approx 2$ ). Contrary to expectation, the intensity of the dislocation band is not linearly dependent on  $I$ , because the recombination centers are saturated. The shape and intensity of the dislocation band are strongly affected by the surface treatment, this being due to different filling of the levels. There are 7 figures. f

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR, Moskva  
(Physics Institute imeni P. N. Lebedev AS USSR, Moscow)

SUBMITTED: April 14, 1962

Card 2/2

40904

S/181/62/004/009/044/045  
B104/B186

5.4300,

AUTHORS: Smirnov, L. S., Vavilov, V. S., and Gerasimenko, N. M.

TITLE: Kinetics of silicon recombination radiation

PERIODICAL: Fizika tverdogo tela, v. 4, no. 9, 1962, 2628-2629

TEXT: The possibility of studying the kinetics of silicon recombination radiation is examined. Rectangular current pulses were fed into Si crystals with p-n junctions. The recombination radiation from the crystal was taken by a photomultiplier, amplified with a broad-band amplifier and observed with an oscilloscope. The crystals had been produced by diffusion of phosphorus and by fusing aluminum on to the surface. The injection coefficient was assumed to remain constant up to current densities of  $10 \text{ a/cm}^2$ . Results: The attenuation of recombination luminescence can be well described by an exponential law. The time constants of attenuation are approximately 2.7 microseconds for crystals with diffused junctions, 1.5 microseconds for crystals with fused junctions. When the crystal is cooled to liquid nitrogen temperature the pulse amplitude does not decrease in proportion to the change in the

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44163

S/181/62/004/012/003/052  
B104/B102

24/550

AUTHORS:

Smirnova, I. V., Chapnin, V. A., and Vavilov, V. S.

TITLE:

Radiation defects in lithium-doped silicon

PERIODICAL:

Fizika tverdogo tela, v. 4, no. 12, 1962, 3373-3380

TEXT: The effect of lithium on the formation of stable radiation defects in silicon and on the annealing of these defects is studied by determining the temperature dependence of the carrier concentration from the Hall effect. The lithium was introduced into Si single crystals by diffusion annealing (550-650°C) from a tin-lithium alloy. The single crystals had a resistivity of 100 ohm·cm; after doping they had n-type conductivity. The carrier concentration lay between  $3 \cdot 10^{14}$  and  $2 \cdot 10^{17}$  cm<sup>-3</sup>. The specimens were irradiated by 0.9-Mev electrons at room temperature. Results: In n-type silicon with lithium up to concentrations of  $(1-2) \cdot 10^{17}$  cm<sup>-3</sup>, shallow energy-levels arise in the range from 0.06 to 0.14 ev below the bottom of the conduction band, which are related to primary radiation defects, e.g., to pairs of interstitial atoms and

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B104/B102

Radiation defects in ...

vacancies which are separated by different distances. The lithium in the Si crystal interacts with these defects. Such interaction is similar to the processes that occur during the annealing of genetically unrelated vacancies and interstitial atoms. The trapping radius has the same order as the lattice constant, ( $r_{\min} = 5.4 \cdot 10^{-8}$  cm). In crystals that, after part of the lithium has been deposited in the defects, are again of p-type conductivity, the levels 0.45 ev, 0.28 ev and 0.21 ev were observed above the top of the valency band. The centers corresponding to the level  $E_v + 0.28$  ev did not disappear completely even during annealing for several hours at 450°C and above; those corresponding to the level  $E_v + 0.21$  ev disappeared completely during annealing at 450°C. There are 4 figures.

ASSOCIATION: Moskovskiy gosudarstvennyy universitet im. M.V. Lomonosova  
(Moscow State University imeni M.V. Lomonosov)

SUBMITTED: June 16, 1962

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S/181/62/004/009/044/645  
B104/B186

Kinetics of silicon recombination...

lifetime. This is explained by a shift of the recombination radiation band, corresponding to band-to-band transitions, into a region of higher sensitivity of the photomultiplier. There are 2 figures. *f.*

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR, Moskva  
(Physics Institute imeni P. N. Lebedev AS USSR, Moscow)

SUBMITTED: June 4, 1962

Card 2/2

: 44168

S/181/62/004/012/015/052  
B104/B102

24.7500

AUTHORS:

Vavilov, V.S., Plotnikov, A.F., and Tkachev, V.D.

TITLE:

Investigating structural defects in silicon single crystals by reference to the photoconductivity

PERIODICAL:

Fizika tverdogo tela, v. 4, no. 12, 1962, 3446-3454

TEXT: The photoconductivity spectra of p- and n-type Si single crystals with different oxygen, boron, and phosphorus concentrations, irradiated by electrons (~1 Mev) from the electrostatic generator of the Laboratoriya fiziki poluprovodnikov (Laboratory of the Physics of Semiconductors) of the FIAN at 100 and 300°K, were investigated with a recording spectrometer designed on the basis of the MKC-12 (IKS-12) monochromator. The specimens were plates (15.2.5.0.8 mm) with palladium contacts (p-type specimens) or with zinc contacts (n-type specimens). Results: Irradiation leads to the appearance of a large number of discrete levels in the forbidden band. The dependence of the shape of the photoconductivity spectrum on the position of the Fermi level, which is related to the excitation of electrons on the different levels, shows

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S/181/62/004/012/015/052  
B104/B102

Investigating structural defects ...

that all levels (Fig. 11) can be related to defects. The higher sensitivity of photoelectric measurements as compared with electric measurements made it possible to prove the existence of a series of centers with different ionization energies. In Si single crystals, irradiation by neutrons produces the same defects as by electrons. The radiation defects which determine the photoconductivity spectrum of Si in the range of 2 to 6  $\mu$ , are not Frenkel' defects. Irradiations at 100°K showed that at room temperature not only simple Frenkel' defects exist, but also associations of these with other types of defects. This makes it possible to study how such associations are formed and to determine the characteristics of defect diffusion. Electrically active impurities (Cu, Au) with concentrations of  $10^{11}$  to  $10^{12}$  cm<sup>-3</sup> could be identified by studying photoconductivity spectra. There are 12 figures.

ASSOCIATION: Fizicheskiy institut im. P.N. Lebedeva AN SSSR Moskva.  
(Physics Institute imeni P.N. Lebedev AS USSR, Moscow)

SUBMITTED: July 6, 1962

Card 2/3

44177

S/181/62/004/012/031/052  
B125/B102

44177  
24.2600

AUTHORS:

Plotnikov, A. F., Tkachev, V. D., and Vavilov, V. S.

TITLE:

The photoconductivity spectra of monocrystals related with residual impurities

PERIODICAL:

Fizika tverdogo tela, v. 4, no. 12, 1962, 3575-3577

TEXT: The photoconductivity spectra of silicon monocrystals ( $\rho \sim 1000 \text{ ohm}\cdot\text{cm}$ ) were examined at  $100^\circ\text{K}$  at constant and alternating excitation (modulating frequency of the light 9 cps). The crystals were either produced by zone melting in vacuo or were grown in quartz crucibles. The measuring apparatus, described by A. F. Plotnikov et al, (PTE<sup>①</sup> 3, 1962) recorded variations in the dark conductivity up to  $10^{-8}$ . The  $\lambda$ -dependences of the relative change  $\Delta\sigma/\sigma$  in the photoconductivity of p-type silicon monocrystals of 500 and 75  $\text{ohm}\cdot\text{cm}$ , have the same step-like form.  $I$  is the intensity of the exciting light. The photoconductivity beyond  $3.2 \mu$  may be related with the known donor level of gold which lies 0.35 ev above the v-band. This level is due to centers whose concentrations vary between  $10^{10}$  and  $10^{11} \text{ cm}^{-3}$ . This concentration of monocrystals produced in quartz

Card 1/3 ① S/120/62/000/003/042/048

S/181/62/004/012/031/052  
B125/B102

The photoconductivity spectra ...

dishes is higher by one order of magnitude than that of silicon produced by vertical zone melting in vacuo. The level at  $1.8 \mu$  corresponds to bipolar excitation, the level at  $2.2 \mu$  corresponds to the acceptor level lying 0.54 ev below the bottom of the c-band and the level  $2.8 \mu$  arises from bipolar excitation by the copper level  $E_v + 0.49$  ev. In the latter

case, minority carriers (electrons) are excited by double optical transitions to the conduction band. The level in the region  $2.3 \mu$  of the  $\lambda$ -dependence of  $\Delta\sigma/\sigma I$  is evidently due to electron excitation from the gold level  $E_c - 0.54$  ev to the conduction band. The broader level below

$2 \mu$  might be due to bipolar electron excitation through 2 levels. The shape of the spectral curves of the photoconductivity of p-type silicon monocrystals (doped with gold up to  $5 \cdot 10^{15} \text{ cm}^{-3}$ ) confirms the above assumption that the impurity photoconductivity in unalloyed Si crystals is caused by gold atoms. In Si monocrystals produced by zone melting in vacuo without any crucible the gold concentration is found to be  $10^{10} - 10^{11} \text{ cm}^{-3}$  and the copper concentration  $10^{11} - 10^{12} \text{ cm}^{-3}$ . In Si monocrystals grown in quartz crucibles or by vertical zone melting the

Card 2/3

The photoconductivity spectra ...

S/181/62/004/012/031/052  
B125/B102

residual impurities, copper and gold, produce local centers with deep levels in the forbidden bands. There are 3 figures.

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR, Moskva  
(Physics Institute imeni P. N. Lebedev AS USSR, Moscow)

SUBMITTED: July 10, 1962

Card 3/3

PLOTNIKOV, A.F.; VAVILOV, V.S.; KOPYLOVSKIY, B.D.

Apparatus for studying the spectra and kinetics of photoconductivity  
in semiconductor crystals. Prib. i tekhn. eksp. 7 no.3:183-187  
My-Je '62. (MIRA 16:7)

1. Fizicheskii institut AN SSSR.  
(Photoconductivity) (Semiconductors)

LOTKOVA, E.N.; VAVILOV, V.S.; SOBOLEV, N.N.

Infrared absorption spectrum of silicon irradiated by fast neutrons.  
Opt.i spektr. 13 no.2:216-221 Ag '62. (MIRA 15:11)  
(Silicon—Spectra) (Neutrons)

VAVILOV, V.S.

Processes of radiation ionization in the germanium and silicon  
crystals. Analele mat 16 no.3:181-196 JI-S '62.

VAVILOV, V.S.; KALASHNIKOV, S.G.

Photoelectric phenomena in semiconductors (Second International  
Conference on Photoconductivity). Usp.fiz.nauk 76 no.4:749-758  
Ap '62. (MIRA 15:7)  
(Semiconductors) (Photoconductivity—Congresses)

VAVILOV, Viktor Sergeyevich; DUBNOVA, V.Ya., red.; SHKLYAR, S.Ya.,  
tekhn. red.

[Effect of radiation on semiconductors] Deistvie izlucheni  
na poluprovodniki. Moskva, Fizmatgiz, 1963. 264 p.  
(MIRA 17:2)

L 15556-63

EWI(1)/EWG(k)/EWI(m)/BDS/EEC(b)-2 AFFTC/ASD/ESD-3

Fz-4 AT/IJP(C)

ACCESSION NR: AP3003876

S/0181/63/005/007/1826/1829

AUTHORS: Tkachev, V. D.; Plotnikov, A. F.; Vavilov, V. S.

TITLE: Spectra of photoconductivity in n-type silica bombarded with high-speed electrons  
21

SOURCE: Fizika tverdogo tela, v. 5, no. 7, 1963, 1826-1829

TOPIC TAGS: photoconductivity, silica, n-type, electron, high-speed electron, conduction band, valence band, forbidden band, center, defect

ABSTRACT: The photoconductivity of n-type silica was studied by means of the setup described by A. F. Plotnikov, V. S. Val'kov, and B. D. Kopylovskiy (PTE, No. 3, 183, 1962). The spectra were investigated with oscillating (modulation frequency of 9 cycles) and steady excitation. The samples were plates cut from single crystals and had contacts attached at the ends. The contacts were Pd and Zn, deposited electrolytically. The bombardment was effected with electrons of 1 Mev. The temperature of the samples during bombardment did not exceed 25-30C, and measurements were made at a temperature near 100K. From the measurements of photoconductivity the authors diagrammed the positions of energy levels in the  
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L 15556-63

ACCESSION NR: AP3003876

forbidden band. This diagram is shown in Fig. 1 (see Enclosure 1). The results, like data on bombardment of p-type silica with electrons and neutrons, attest to a "set" of several centers, the nature of most being as yet unexplained. The "radiation" origin of centers with levels at  $E_c - 0.16$ ,  $E_c - 0.40$ ,  $E_v + 0.54$ , and  $E_v + 0.45$  eV is not questioned. These levels are starred in Fig. 1. It is possible that some of the levels are initially present in the material, not developing anew but merely appearing because of the capture of equilibrium carriers by defects and because of favorable conditions for measuring photoconductivity in bombarded silica at low temperatures. "The authors express their sincere thanks to G. N. Galkin, V. M. Malovetskaya, and V. I. Provkinaya for valuable advice and critical remarks and to Ye. M. Divil'kovskaya (deceased) for aid in the work." Orig. art. has: 6 figures.

ASSOCIATION: Fizicheskii institut im. P. N. Lebedeva AN SSSR, Moscow (Physical Institute, Academy of Sciences, SSSR)

SUBMITTED: 30Jan63

DATE ACQ: 15Aug63

ENCL: 01

SUB CODE: PH

NO REF SOV: 005

OTHER: 002

Card 2/3

TKACHEV, V.D.; PLOTNIKOV, A.F.; VAVILOV, V.S.

Nature of local centers with deep-seated levels in silicon  
irradiated by fast electrons. Fiz. tver. tela 5 no.11:3188-3194  
N '63. (MIRA 16:12)

1. Fizicheskii institut imeni Lebedeva AN SSSR, Moskva.

L 13030-63 EWT(1)/EWG(k)/EWP(q)/EWT(m)/BDS/EEC(b)-2 AFFTC/  
 ASD/ESD-3 Pz-4 JD/AT  
 ACCESSION NR: AP3000624

3/0181/63/005/005/1417/1422

AUTHOR: Akimchenko, I. P.; Vavilov, V. S.; Plotnikov, A. F.

TITLE: Spectra and kinetics of photoconductivity associated with simple structural defects in single crystals of germanium

SOURCE: Fizika tverdogo tela, v. 5, no. 5, 1963, 1417-1422

TOPIC TAGS: photoconductivity, capture cross section, vacancy, interstitial, Ge, Au

ABSTRACT: The authors have investigated the photoconductivity associated with deep levels of radiation effects arising during bombardment by electrons (1 mev) of very pure single crystals of Ge and of single crystals alloyed with Au. They conclude that a detected level of  $E_{\text{sub V}} + 0.42 \text{ ev}$ , belongs to an interstitial atom. The capture cross section corresponding to relaxation at the latter level was computed to be 3 times  $10 \text{ sup } -17 \text{ Sq/cm}$ . From this value the effectiveness of inserting centers and the results fell within the limits of experimental error. "In conclusion the authors consider it their pleasant duty to express thanks to M. I. Iglitsy\*n for discussing the results, and to M. I. Ginzburg and G. P. Proshko for supplying the single crystals of germanium." Orig. art. has: 10 figures.

Association: Inst. of Physics, Academy of Sciences, USSR.

Card 1/2/

VAVILOV, V. S.

International Conference on Defects in Crystals held at Kyoto,  
September 7-12, 1962. Usp. fiz. nauk 79 no.1:153-159 Ja '63.  
(MIRA 16:1)

(Crystals—Congresses)



L 24498-65

ACCESSION NR AM4040591

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OTHER: 184

Card 2/2

VAVILOV, V. S.; TKACHEV, V. D.; SAVCHENKO, A. N.

"On the nature of local centers with deep energy levels in silicon irradiated by fast electrons."

report submitted for Symp on Radiation Damage in Semiconductors, Royaumont,  
16-18 Jul 64.

ACCESSION NR: AP4047462

S/0120/64/000/005/0079/0080

AUTHOR: Vavilov, V. S.; Kolomenskaya, T. I.; Vintovkin, S. I.; Chukichev, M.V. B

TITLE: Generation of minority carriers in silicon by fast electrons

SOURCE: Priory\* i tekhnika eksperimenta, no. 5, 1964: 79-80

TOPIC TAGS: semiconductor research, silicon counter

ABSTRACT: The theoretical spatial distribution of the ionization energy loss in Si given by B. Ya. Yurkov (Zh. tekhn. fiz., 1958. 28, 1159) has been experimentally verified. A p-n junction was prepared by diffusion P in p-Si having a resistivity of 1 ohm-cm. Experimental curves of the average ionization loss vs. the depth of penetration, for electron beams with initial energies of 250, 500, 700, and 900 kev are presented. Within the usual experimental errors, the

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ACCESSION NR: AP4047462

curves show satisfactory agreement with the theoretical curve. Orig. art. has:  
2 figures.

ASSOCIATION: Moskovskiy gosudarstvennyy universitet im. M. V. Lomonosova  
(Moscow State University)

SUBMITTED: 13Nov63

ENCL: 00

SUB CODE: EC

NO REF SOV: 002

OTHER: 003

Card 2/2

S/0181/64/006/001/0329/0331

ACCESSION NR: AP4011786

AUTHORS: Kryukova, I. V.; Vavilov, V. S.

TITLE: Orientation dependence of the formation of radiation defects in n-type silicon

SOURCE: Fizika tverdogo tela, v. 6, no. 1, 1964, 329-331

TOPIC TAGS: radiation defect, n type silicon, electron bombardment, combination center, minority carrier, p-n junction, minority carrier lifetime, electron flux, capture cross section, thermal velocity, carrier velocity

ABSTRACT: Determination of orientation dependence is difficult because of the necessity of working with very thin samples (10-20 microns) and avoiding loss of initial direction of incident particles by scattering on atoms of the test material. The authors used a different method, proposed by V. S. Vavilov, V. M. Patskevich, B. Ya. Yurkov, and P. L. Glazunov (Fiz, 2, 1431, 1960), which yields data on orientation dependence by measuring dependence of resistivity changes on depth of electron penetration. A single crystal of n-type Si was used. Defects introduced by radiation were recorded by measuring the lifetime ( $\tau$ ) of minority carriers dur-

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ACCESSION NR: APL011786

ing bombardment. To record changes in this lifetime, the authors measured the short-circuited current ( $I_{sc}$ ) in the circuit of a crystal with a p-n junction during bombardment by a stream of electrons. The number of combination centers introduced by radiation in small doses is equal to the product of electron flux ( $\phi$ ) and the rate of defect production ( $\gamma$ ) (by  $\gamma$  is meant the ratio of number of defects per cu cm to the electron flux per sq cm). The relationship among these values is then

$$\Delta\left(\frac{1}{\tau}\right) \sim \Delta\left(\frac{1}{\tau}\right) = \tau \phi \sigma v f(E_i - E_f),$$

where  $\sigma$  is the capture cross section of carriers by the given center,  $v$  is the thermal velocity of the carriers, and  $f(E_i - E_f)$  is the function of level filling. Bombardment by electrons of 1 Mev was carried out at room temperature. The relationship between electron flux and change in short-circuited current (proportional to lifetime of carriers) for various directions of bombardment is shown in Fig. 1 of the Enclosure. The observed orientation dependence is associated with the presence of interstitial positions in a loose lattice of the diamond type. "The authors thank S. I. Vintovkin for his aid in bombarding the samples." Orig. art. has: 1 figure.

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ACCESSION NR: A4011786

ASSOCIATION: Moskovskiy gosudarstvennyy universitet im. M. V. Lomonosova (Moscow State University)

SUBMITTED: 05Sep63

DATE ACQ: 11Feb64

ENCL: 01

SUB CODE: PH

NO REF SOV: 002

OTHER: 003

Card 3/4

ACCESSION NR: AP4034920

S/0181/64/006/005/1406/1412

AUTHOR: Vavilov, V. S.; Nolle, E. L.; Yagorov, V. D.; Vintovkin, S. I.

TITLE: Radiative recombination in cadmium telluride as a result of excitation by fast electron pulses

SOURCE: Fizika tverdogo tela, v. 6, no. 5, 1964, 1406-1412

TOPIC TAGS: radiative recombination, cadmium telluride, CdTe, laser material, stimulated emission, semiconductor

ABSTRACT: The recombination radiation spectrum of CdTe excited by fast electrons was investigated in the photon energy interval from 0.7 to 1.6 eV and at temperatures between 10 and 300K. The p-type samples with resistivity of  $\sim 10$  ohm-cm were excited by 1 MeV electron pulses of 2.5  $\mu$ sec duration from an electrostatic generator. The repetition frequency was 10 cps, and the current density per electron pulse varied between 0.3 and 0.5 mA/cm. Since a 30 hr exposure to this type of irradiation did not affect the recombination

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ACCESSION NR: AP4034920

radiation spectrum, it was assumed that the effect of the formation of radiation defects could be neglected. It was found that at 10K the recombination radiation spectrum consists of three intense bands with maxima at photon energies of  $1.05 \pm 0.01$ ,  $1.47 \pm 0.01$ , and  $1.59 \pm 0.01$  ev. The short-wave emission band is located in the region of the fundamental absorption band. Analysis of the data shows that vertical transitions with emission of optical phonons with zero momentum occur in CdTe and that the probability of such processes is high. According to criteria developed in: Basov, N. G., O. N. Krokhin, Yu. M. Popov. ZhETF, v. 4, 1961, p. 1203, it may, therefore, be possible to obtain laser action in CdTe at low temperatures when the nonequilibrium charge carrier concentration is considerably smaller than that corresponding to the degenerate state. Orig. art. has: 6 figures.

ASSOCIATION: Fizicheskii institut imeni P. N. Lebedeva AN SSSR  
(Physics Institute, AN SSSR)

Cord 2/3

ACCESSION NR: AP4034920

SUBMITTED: 20Nov63

SUB CODE: PN

DATE ACQ: 20May64

NO REF SOV: 004

ENCL: 00

OTHR: 006

Card 3/3

ACCESSION NR: AP4041733

S/0181/64/006/007/2192/2194

AUTHORS: Tyapkina, N. D.; Krivopolenova, M. M.; Vavilov, V. S.

TITLE: Electric properties of beryllium doped p-type germanium

SOURCE: Fizika tverdogo tela, v. 6, no. 7, 1964, 2192-2194

TOPIC TAGS: germanium, beryllium, electric conductivity, carrier density, temperature dependence

ABSTRACT: In order to determine the upper acceptor energy level of beryllium in compensated and higher-resistivity germanium specimens, the authors measured the temperature dependence of the carrier density and of the electric conductivity of doped germanium plates 2 x 3 x 15 mm in the temperature range 300--55K. The compensating impurity was phosphorus. The plates were cut from the ingot perpendicular to the [111] crystal growth axis. The measurements were made in a double metallic cryostat. A null method was used with a

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ACCESSION NR: AP4041733

high-resistance potentiometer. The magnetic field reached 4600 Oe. Eight samples from four ingots were tested. The results show that in all samples the carrier density is exponential in the reciprocal temperature. The ionization energy was determined from the slope of plots of  $\ln(pT)^{3/2}$  against  $10^3/T$ , and its value  $(0.064 \pm 0.003 \text{ eV})$  is close to that obtained by others and also close to that calculation by the "helium" model, which is thus shown to be applicable to beryllium in germanium. Orig. art. has: 1 figure and 1 table.

ASSOCIATION: Moskovskiy gosudarstvennyy universitet im. M. V. Lomonosova (Moscow State University)

SUBMITTED: 13Feb64

ENCL: 02

SUB CODE: SS, EC

NR REF SOV: 002

OTHER: 004

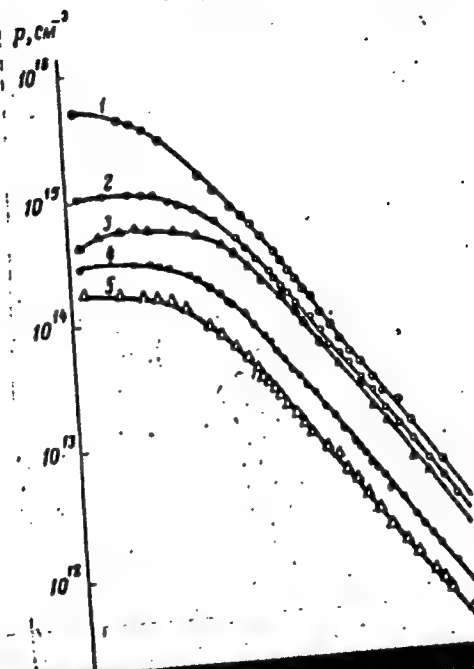
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ACCESSION NR: AP4041733

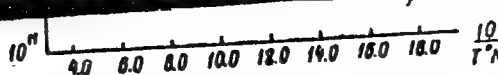
ENCLOSURE: 01

Dependence of carrier density on  
the temperature for different  
samples  
Sam



Card

3/4



ACCESSION NR: APh041733

ENCLOSURE: 02

Values of ionization energy in the investigated samples

1	2	3	4	5
N of sample	Concentration of Be, $10^{-11}$ cm $^{-3}$	Concentration of P, $10^{-11}$ cm $^{-3}$	$N_p / N_{Be}$	Ionization energy, eV
157 (2)	0.8	1.4	1.75	0.064
169 (1)	0.83	1.5	1.81	0.064
169 (5)	0.75	0.9	1.20	0.063
184 (5)	1.2	1.4	1.17	0.064
181 (6)	6.8	8.4	1.24	0.064

1 - sample no. 2 - beryllium density in  $10^{-5}$  cm $^{-3}$ , 3 - phosphorus density  
4 - ionization energy, eV

Card: 4/4

ACCESSION NR: AP4039659

S/0181/64/006/006/1718/1723

AUTHOR: Akimchenko, I. P.; Vavilov, V. S.; Plotnikov, A. P.

TITLE: Some data on radiation defects obtained through investigations of photoconductivity spectra of germanium irradiated with fast electrons

SOURCE: Fizika tverdogo tela, v. 6, no. 6, 1964, 1718-1723

TOPIC TAGS: radiation defects, fast electron irradiation, p type germanium, n type germanium, germanium, fast electron irradiated germanium, germanium photoconductivity spectrum, irradiated germanium photoconductivity spectrum, forbidden zone

ABSTRACT: The following types of Ge single crystals have been irradiated by fast electrons with energies  $\sim 1$  Mev at room temperature: (a) n-type with initial resistivities  $\rho$  of 3 and 56 ohm $\cdot$ cm; (b) dislocationless n-type,  $\rho \sim 3$  ohm $\cdot$ cm; (c) p-type with a residual impurity concentration of  $10^{11}$  to  $10^{13}$  at/cm $^3$ . The ohmic contacts were realized by the deposition of colloidal graphite. Photoconductivity spectra were measured at  $\sim 100$  K in the 1.7 to 10  $\mu$  wavelength range.

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ACCESSION NR: AP4039659

In the irradiated specimens the Fermi level was located 0.10 to 0.17 eV below the bottom of the conduction band. Some of the conclusions drawn from the results of the investigation are: 1) following irradiation with a flux of  $6 \times 10^{15}$  el/cm<sup>2</sup>, the photoconductivity spectra of n-type specimens showed the occurrence of a structure which can be connected with electron transitions from local levels  $E_c - 0.33$ ,  $E_c - 0.37$  and  $E_c - 0.43$  eV to the conduction band. When the total electron flux is increased to  $3 \times 10^{16}$  el/cm<sup>2</sup> the specimen acquires characteristics of p-type Ge; 2) spectra of type (b) specimens show that vacancy concentration increases almost proportionally with increased flux and that at a certain value of the electron flux there is an increase (by almost one order of magnitude) in the concentration of centers which yield a constant distribution of photoconductivity signals in the 2.5—1.9  $\mu$  wavelength range; 3) a new maximum was detected in the spectra of type (c) specimens which occurred in the presence and disappeared in the absence of bias lighting from the region of natural absorption; 4) at wavelengths up to 5  $\mu$ , the spectra of type (c) specimens showed a build-up of signals connected with electron transition to level  $E_v + 0.33$  eV in the presence of a Ge filter; when no filter was used a maximum appeared at a wavelength of 3.15  $\mu$ ;

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ACCESSION NR: AP4039659

5) in nonirradiated type (c) specimens the disturbance which introduces level  $E_v + 0.33$  ev is due to copper atoms, while in the irradiated type (c) specimens it is due to the joint action of copper atoms and vacancies; 6) for the irradiated (c) specimens the hole-capture cross-section of level  $E_v + 0.33$  ev is at  $100^\circ\text{K}$   $5 \times 10^{-19}$  cm<sup>2</sup>.

Orig. art. has: 9 figures.

ASSOCIATION: Fizicheskii institut im. P. N. Lebedeva AN SSSR,  
Moscow (Physics Institute, AN SSSR)

SUBMITTED: 28Dec63

DATE ACQ: 19Jun64

ENCL: 00

SUB CODE: NP

NO REF SOV: 007

OTHER: 000

Card 3/3

L 18851-65 EWT(1)/EWC(k)/EWT(m)/T/EWP(t)/EWP(b)/EWA(n) Feb IJF(c)/SSD/AFWL/  
AEDC(a)/ESD(gs) JD/AT  
ACCESSION NR: AP4043355 S/0181/64/006/008/2361/2368

AUTHORS: Gippius, A. A.; Vavilov, V. S.

TITLE: On the mechanism of radiative recombinations at dislocations  
in germanium 27

SOURCE: Fizika tverdogo tela, v. 6, no. 8, 1964, 2361-2368

TOPIC TAGS: germanium, dislocation net, radiative recombination,  
forbidden band, temperature dependence, hole conduction, level  
transition

ABSTRACT: The paper is a continuation of the authors' earlier work  
on Ge crystals with  $10^3$ -- $10^4$  dislocations/cm<sup>2</sup> (FTT, v. 4, 2426, 1962)  
which established: (1) the presence of several components in the re-  
combination radiation spectrum of dislocations indicating that  
several levels were active simultaneously; (2) a dependence of the  
radiation band profile on the Fermi level position, indicating hole

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ACCESSION NR: AP4043355

transitions to levels in the upper half of the forbidden band;  
(3) a sublinear dependence of the dislocation band intensity on the injection current at high current densities, suggesting internal processes in radiation centers giving rise to saturation. The present paper extends this work to higher dislocation densities ( $10^5$ -- $10^6$  cm<sup>-2</sup>) and therefore stronger recombination radiation, which was easier to study and resolve. It was found that an increase of the equilibrium or injected electron density produced new long- (2.6--2.7  $\mu$ ) and short-wavelength (1.9--2.1  $\mu$ ) components, or intensified intermediate wavelengths (2.4  $\mu$ ); this indicated that hole transitions did not start from the valence band. The half-widths  $\Delta E$  and the positions of the maxima of the dislocation bands were measured as a function of temperature (80--200K). Up to 170K the value of  $\Delta E$  was independent of temperature. This, and the observations referred to above, indicated that holes were captured by excited states and that radiative transitions occurred within centers. The observed rise of  $\Delta E$  with temperature above

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ACCESSION NR: AP4043355

4  
170K indicated the presence of another band which was very weak at lower temperatures. Saturation in the dependence of the dislocation band intensity on the injection current showed that radiation centers were not whole dislocations but jogs, nodes or other irregularities in dislocations. The actual positions of the levels of radiation centers could not be established from the available data. "The authors thank B. M. Vul, A. V. Spitsin, and V. D. Yegorov." Orig. art. has: 7 figures.

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR, Moscow  
(Physics Institute AN SSSR)

SUBMITTED: 24Feb64

ENCL: 00

SUB CODE: SS

NR REF SOV: 005

OTHER: 002

Card 3/3

ACCESSION NR: AP4041737

S/0181/64/006/007/2200/2202

AUTHORS: Gippius, A. A.; Vavilov, V. S.; Konoplev, V. S.

TITLE: Determination of the yield of recombination radiation connected with dislocations in germanium

SOURCE: Fizika tverdogo tela, v. 6, no. 7, 1964, 2200-2202

TOPIC TAGS: recombination emission, quantum yield, dislocation effect, lead sulfide, photoconductive device

ABSTRACT: The yield is defined here as the ratio of the number of quanta of recombination radiation to the total number of acts of recombination on the given type of centers. Since this yield must be measured when the dislocations play a predominant role in the recombination of the non-equilibrium carriers, the tested sample was bombarded with a beam of  $\sim 1$  MeV electrons from a Van de Graaff accelerator. The receiver was a lead-sulfide photoresistance calibrated with

Card 1/3

ACCESSION NR: AP4041737

the aid of a black body. n-type germanium with electron density  $n_0 \sim 5 \times 10^{14} \text{ cm}^{-3}$  and dislocation density  $N \sim 10^5 \text{ cm}^{-2}$  was used. The dislocations were introduced by an abrupt change in the thermal conditions during the growth of the crystal. The tests were made at approximately 80K. The quantum yield was found to be quite small, indicating that most recombinations on the dislocations are nonradiative. Some explanations for this phenomenon are discussed. The results obtained for the quantum yield and for some related quantities are compared with data by others. "The authors thank A. V. Spitsy\*n for determining the carrier density in the sample and S. I. Vintovkin and V. V. Mikhaylov for help with the measurements." Orig. art. has: 1 table.

ASSOCIATION: Fizicheskiy institut im. P. N. Lebedeva AN SSSR  
(Physics Institute, AN SSSR)

SUBMITTED: 24Feb64

SUB CODE: SS

NR REF SOV: 005

ENCL: 01

OTHER: 001

Card 2/3

ENCLOSURE: 01

ACCESSION NR: AP4041737

Results of determination of quantum yield

№ образца 1	$N_0 \cdot 10^{-14}, \text{cm}^{-3}$	$N_d \cdot 10^{-14}, \text{cm}^{-3}$	$j, \text{mks/cm}^3$ 2	$\frac{j \cdot 10^{-19}}{\text{cm}^{-3} \cdot \text{cm}^{-1} \cdot \text{sec}^{-1}}$ 3	$\frac{j \cdot 10^{-19}}{\text{cm}^{-3} \cdot \text{cm}^{-1} \cdot \text{sec}^{-1}}$ 3	$Y_{\text{rel}} \cdot 10^4$ 4
4	6.5	5	0.5 0.75	1.7 2.5	6.2 7.7	3.7 3.1
5	5.2	4	0.5 1.0	1.7 3.4	3.8 6.4	2.2 1.9
7	3.8	10	1.25 2.25	4.2 7.4	8.2 12.8	1.9 1.7

1 - sample no. 2 -  $j$  (fast-electron density), microamp/cm<sup>3</sup>,  
3 =  $g \cdot 10^{-19} \text{ cm}^{-3} \text{ sec}^{-1}$ , 4 = quantum yield, 10<sup>4</sup>

Card 3/3

ACCESSION NR: AP4044931

S/0181/64/006/009/2634/2637

AUTHOR: Vavilov, V. S.; Kryukova, I. V.; Chukichev, M. V.

TITLE: Effect of lithium on recombination in n-type silicon bombarded by fast electrons

SOURCE: Fizika tverdogo tela, v. 6, no. 9, 1964, 2634-2637

TOPIC TAGS: silicon, lithium, p n junction, recombination, carrier mobility, radiation defect

ABSTRACT: This research is the result of earlier studies by the authors (FTT v. 12, 3373, 1962) in which it was shown that an increase of the lithium content in silicon containing oxygen reduces the rate of A-center formation, and is aimed at ascertaining the extent to which introduction of lithium reduces the concentration of the recombination levels. Lithium was chosen because its ions have high mobility and should interact with the radiation defects at relatively low temperatures. The effect of the lithium was determined by measuring the lifetimes of the minority carriers in the silicon

Card 1/2

L 1404-65  
ACCESSION NR: AP4044931

by electrons in the presence of lithium impurities. Lithium was introduced into the silicon by diffusion at 550—650C, and its content ranged from 0.1 to 1 per cent. The influence of the radiation-induced defects on the minority carrier lifetime was determined by measuring the short circuit current produced in the circuit of a crystal with a p-n junction exposed to hard radiation. The tests confirmed the earlier results obtained by measuring the Hall effect, that silicon doped with lithium has a much lower minority carrier recombination rate and a much lower recombination center content. "The authors are grateful to Zh. R. Panosyan, S. I. Vintovkin, and T. Granina for help with the work." Orig. art. has: 3 figures and 3 formulas.

ASSOCIATION: Moskovskiy gosudarstvennyy universitet im. M. V. Lomonosova (Moscow State University)

SUBMITTED: 13Mar64

SUB CODE: SS

ENCL: 00

NO REF SOV: 003

OTHER: 005

Card 2/2

VAVILOV, V.S.; KOLOMENSKAYA, T.I.; VINTOVKIN, S.I.; CHUKICHEV, M.V.

Generation of nonequilibrium carriers by fast electrons in  
silicon. Prib. i tekhn. eksp. 9 no.5:79-80 S.-O '64.  
(MIRA 17:12)

1. Fizicheskiy fakul'tet Moskovskogo gosudarstvennogo  
universiteta.

L 31353-65 EWT(1)/EWT(m)/EPP(c)/EPP(n)-2/T/EWA(h) Pr-4/Fu-4/Peb IJP(c)/  
AS(mp)-2/SSD/AFWL/AFETR/ESD(gs)/ESD(t) GG/AT  
ACCESSION NR: AP4049828 S/0053/64/084/003/0431/0450

AUTHOR: Vavilov, V. S.

TITLE: The nature and energy spectrum of radiation defects in semiconductors

SOURCE: Uspekhi fizicheskikh nauk, v. 84, no. 3, 1964, 431-450

TOPIC TAGS: radiation defect, radiation damage, impurity content, electron bombardment, germanium, silicon, annealing doping, intermetallic semiconductor

ABSTRACT: This review lists the various investigations performed in recent years on the interaction between radiation-induced defects and the impurities or defects initially present in a semiconductor crystal, with attention to the number and distribution of the local levels contained by irradiated crystals. The information that can be deduced with the aid of various research methods (studies of structure and of photoconductivity spectra, optical studies, spin resonance techniques, combination of low-temperature irradiation with optical and electrical measurements) or by using crystals with low impurity contents is briefly identified. The section headings are: 1 Introduction.

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L 31353-65

ACCESSION NR: AP4049828

2. Energy spectrum of local centers in silicon irradiated with fast electrons. 3. Radiation defects in lithium-doped silicon. 4. The nature of radiation defects in single crystals of very pure germanium and of gold-doped germanium. 5. Interaction between radiation defects and impurities during annealing. 6. The generation of radiation defects in intermetallic semiconductors. Orig. art. has: 12 figures, 12 formulas, and 1 table.

ASSOCIATION: None

ENCL: 00

SUBMITTED: 00

OTHER: 027

SUB CODE: SS

NR REF SOV: 019

Card 2/2

VAVILOV, Viktor Sergeyevich, doktor fiz.-matem. nauk, prof.;  
FAYNBOYM, I.B., rev.

[Semiconductors and radiation] Poluprovodniki i izlu-  
chenia. Moskva, Znanie, 1965. 31 p. (Novoe v zhizni,  
nauke, tekhnike. IX Seriya: Fizika, matematika, astro-  
nomia, no.12) (MIRA 18:6)

L 29974-65 EWT(1)/EWT(m)/EPF(c)/EPF(n)-2/EEI(t)/T/ENP(t)/ENP(b) PE-6/PT-4/PJ-4  
IJP(c) JJ/GG/AT S/0181/65/007/002/0502/0505

ACCESSION NR: AP5005291

AUTHOR: Vavilov, V. S.; Vintovkin, S. I.; Lyutovich, A. S.; Plotnikov, A. F.; Sokolova, A. A. 57  
55  
B

TITLE: Radiation structure defects in very pure monocrystals of silicon 19 16 7

SOURCE: Fizika tverdogo tela, v. 7, no. 2, 1965, 502-505

TOPIC TAGS: silicon, photoconductivity, defect, radiation effect, electron bombardment

ABSTRACT: The photoconductivity spectrum of very pure monocrystals of p-type silicon was investigated prior to and after irradiation with 1-Mev electrons. The samples were prepared by crucible-free zone melting of very pure silicon. The resistivity of the samples was 20 ohm-cm, the lifetime of the minority carriers 100-1000 msec, and the hole mobility 200-350 cm<sup>2</sup>/v-sec. The crystals had  $\sim 5 \cdot 10^{11}$  donors/cm<sup>3</sup> and  $5 \cdot 10^{12}$  acceptors/cm<sup>3</sup>. The 12 x 2.5 x 0.4 mm samples were irradiated at room temperature and at the temperature of liquid nitrogen with a flux of  $3 \cdot 10^{15}$  electrons/cm<sup>2</sup>. The photoconductivity of samples with a resistivity of 1030 ohm-cm containing  $\sim 3 \cdot 10^{16}$  atoms of oxygen per cm<sup>3</sup> was also investigated. The experiment showed that the main impurity present in the crystal samples was

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ACCESSION NR: AP5005291

boron, the concentration of which was  $5-10 \cdot 10^{12}$  atoms/cm<sup>3</sup>. Electron bombardment at 80K resulted in the appearance of a continuous distribution of allowed states in the forbidden gap probably associated with point radiation defects. After heating of the samples to room temperature, only one discrete level, the  $E_v + 0.45$  eV level, was found in the forbidden gap when the concentration of oxygen atoms was small; however, three levels ( $E_c - 0.16$ ,  $E_v + 0.30$ , and  $E_v + 0.45$  eV) were found in samples with a large concentration of oxygen atoms. The density of other electrically active impurities was lower by 1.5—2 orders of magnitude. Electron irradiation at room temperature did not change the resistivity of the samples. Bombardment at 80K increased the resistivity of samples quite sharply, although it then leveled off to a constant value. Resistivity decreased and returned practically to its initial value after irradiation was ceased. Considerable fluctuation of photoconductivity (noise) was observed in extremely pure crystals irradiated at 80K. Bombardment of the not very pure samples gradually decreased the lifetime of charge carriers; however, room-temperature irradiation of very pure crystals with fluxes up to  $5 \cdot 10^{16}$  electrons/cm<sup>2</sup> hardly affected the lifetimes. Bombardment of very pure crystals at 80K decreased the lifetimes by 3—4 orders of magnitude. Initial lifetimes were restored almost completely after irradiation was stopped. [CS]

Orig. art. has: 2 figures.

Card 2/3

L 29974-65

ACCESSION NR: AP5005291

ASSOCIATION: Fizicheskiy institut imeni Lebedev AN SSSR, Moscow (Physics Institute,  
AN SSSR); Fiziko-tekhnicheskiy institut AN UzSSR, Tashkent (Physicotechnical In-  
stitute, AN UzSSR)

SUBMITTED: 29Jul64

ENCL: 00

SUB CODE: SS, NP

NO REF SOV: 007

OTHER: 000

ATD :RESS: 3196

Card 3/3

14129-15 11/11/1965 (m, T/END(t), REC(b)-2/END(b), EGA(c) P1-1 JIP(c)  
 ACCESSION NR: AP0005317

AUTHOR: Gippins, A. A., Vavilov, V. G., Goncharov, I. A., Murashov, M. S.

TITLE: Radiative recombination in crystals of germanium with large dislocation density

SOURCE: Fizika tverdogo tela, v. 7, no. 2, 1965, 645-647

TOPIC TAGS: radiative recombination, dislocation, germanium

ABSTRACT: The mechanism of radiative recombination on dislocations proposed earlier by two of the authors (Gippins, A. A., and V. G. Vavilov, Fizika tverdogo tela, 4, 1964, 2361) has been substantiated by experiment. The measurements were performed on large dislocation density germanium crystals with dislocation densities of  $10^5$  and  $10^6$  cm<sup>-2</sup>. The photoluminescence spectra of the samples from the dislocation-free region and from the dislocation region at the 0.4-micron wavelength were measured. The results of the experiment are in good agreement with the theoretical predictions. The results indicate that the recombination is due to dislocations, "rather than to the dislocation cores."

Card 1/2

I 41309-65

ACCESSION NR: AP5005317

for the 2-4 micron wave length. The total mass of the particles of the  
dislocation band is 10<sup>-10</sup> g. The dislocation band is a structure of  
reaching a saturation value. The dislocation band is a structure of  
centers connected with dislocation band.

ASSOCIATION: Fizicheskii Institut im. P. N. Lebedeva AN SSSR, Moscow  
Institute, AN SSSR)

SUBMITTED: 19Aug64

ENCL: 00

SUB CODE: SS, GC

NO REF SOV: 002

OTHER: 005

ATD PRESS: 3209

Card

2/2



ACCESSION NO. A-11111

... the short wavelength emission

... radiation spectra of Ge not containing ... were obtained in order to separate recombination radiation associated with defects from that associated with dislocations. Only the intrinsic band was observed in the 1.5—3 micron region of recombination spectra of the initial samples (resistivity of  $\sim 10^5 \text{ ohm-cm}$ ). In the impurity region (wavelength  $> 1.8 \text{ microns}$ ) a very weak phonon emission, probably associated with point defects, was observed. The point defects contributing ... a relatively wide emission band with a peak ...

... contribution of radiation ... Fig. 2 shows that annealing affects the band, which indicates that ... The quantum yield of recombina-

Card 2/5

Card 3/5

AUTHOR: Vavilov, V. S.; Nolle, E. L.; Yegorov, V. D.

TITLE: New data on the spectrum of recombination radiation of cadmium telluride under electron excitation

SOURCE: Fizika tverdogo tela, v. 7, no. 3, 1965, 934-936

TOPIC TAGS: recombination radiation, CdTe recombination radiation, recombination radiation spectrum, CdTe recombination radiation spectrum

ABSTRACT: Experimental data are presented on the fine structure of the CdTe recombination spectrum under powerful (up to 140 kev) electron-beam (1.2 mm in diameter) pulses. A specimen 0.5 mm thick, cut out of a CdTe single crystal obtained by the method of oriented growth, was investigated as an object of a helium crystal. At each of three lines of recombination radiation were observed. The maxima were observed at higher beam densities. The maxima were observed at photon energies of 1.588, 1.585, and 1.582 ev. A 1-mev beam with increased to 0.001 ev, with maxima at 1.588, 1.585, and 1.582 ev. A 1-mev beam with a density of 0.5 mamp/cm<sup>2</sup> from an electron generator produced a maximum at

Cord 1/2

L 34090-65

ACCESSION NO AP5006917

2

SECRETARY OF DEFENSE  
OFFICE OF THE SECRETARY  
WASHINGTON, D.C. 20301

L 45645-65 EWT(n)/EWP(b)/EWP(t) IJP(c) JD/JG

12/0181/65/007/004/1252/1254

ACCF LON NRI AP5010751

AUTHOR: Tyapkina, N. D.; Vavilov, V. S.

TITLE: Extrinsic conductivity of p-type germanium with beryllium

SOURCE: Fizika tverdogo tela, v. 7, no. 4, 1965, 1252-1254

TOPIC TAGS: germanium, p-type germanium, beryllium doped germanium, phosphorus doped germanium, extrinsic photoconductivity, photoresponse

ABSTRACT: The dependence of photoresponse on photon energy was investigated in several samples of germanium crystal prepared from melt and doped with beryllium and phosphorus. The measurements were made at about 5K by switching the light beam from the sample to an illumination meter. Photoconductivity was measured by the use of an a-c current with a light-flux-modulation frequency of 9 cps. The curves of the dependence displayed a number of minima separated by equal intervals of 37 Mev, corresponding to the energy of the transverse optical phonon at  $k = 0$ . The shape of the curves in the range of 50—70 Mev indicated levels of absorption by lattice oscillations. The origin of the additional minima in the range of 80—130 Mev was

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L 45645-65  
ACCESSION NR: AP5010751

not determined. An attempt was also made to determine the distance of the impurity level from the band edge and to compare it to the same value in cadmium-doped germanium. The ionization energy of the upper acceptor level due to beryllium appears to be 68 MeV, as compared to 50 MeV due to cadmium. Orig. art. has: 1 table and 2 figures [ZL]

ASSOCIATION: Moskowskij gosudarstvennyy universitet im. M. V. Lomonosova (Moscow State University)

SUBMITTED: 13Nov64

ENCL: 00

SUB CODE: SS

OTHER: 006

ATD PRESS: 3244

NO REF COPY: 003

Card 2/27B

I 52000-65 EPA(w)-2/ENT(1)/SEC(t)/ENA(x)-2 Pz-6 IOP(s) AT  
 ASSOCIATION NO: UR/0181/65/007/005/1558/1559

AUTHOR: Vavilov, V. S.; Rolle, E. L.; Maksimovskiy, S. N.

TITLE: Probability (yield) of radiative recombination in cadmium telluride under electronic excitation

SOURCE: Fizika tverdogo tela, v. 7, no. 5, 1965, 1558-1559

TOPIC TAGS: cadmium telluride, electron excitation, radiative recombination, recombination yield, recombination probability, energy yield

ABSTRACT: This is a continuation of earlier investigations (FTT v. 6, 1406, 1964; v. 7, 1444) of the spectrum of radiative recombination of electron-excited CdTe. The purpose of the present research was to determine the energy yield of the CdTe recombination radiation when excited with pulses of  $10^{10}$  electrons at a pulse current density up to  $0.75 \text{ amp/cm}^2$ . The sample, in the form of a plate  $0.7 \text{ mm}$  thick with cleaved front surface, was mounted on the cold finger of a helium cryostat. The exciting electron beam was incident at  $45^\circ$  on the cleaved surface and the recombination radiation was measured with a photomultiplier in a small

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L 52000-65

ACCESSION NR: AP5012577

solid angle perpendicular to the cleaved surface. Investigations at current densities of 10<sup>4</sup>—10<sup>5</sup> amp/cm<sup>2</sup> and in the temperature interval 10—293K yielded the results shown in Fig. 1 of the Enclosure. "The authors are sincerely grateful to V. D. Yegorov, G. P. Golubev, and V. S. Maslennikov for help with the work and to E. M. Yuz and A. A. Shchegolev for assistance in the results and critical remarks." Orig art. has: 1 figure and 1 formula.

ASSOCIATION: Fizicheskii institut im. Lebedeva AN SSSR, Moscow (Physics Institute AN SSSR)

SUBMITTED: 10Dec64

ENCL: 01

SUB CODE: GC, IC

NO REF SOV: 002

OTHER: 001

ATD PRESS: 4009

Card 2/3

L 15738-66 EWT(1)/EWP(e)/EWT(m)/ETC(f)/EWG(m)/T/EWP(t)/EWP(b) LJP(c) JD/JG/  
 ACC NR: AP6000900 SOURCE CODE: UR/0181/65/007/012/3702/3704  
 AT/WH  
 AUTHORS: Golubev, G. P.; Vavilov, V. S.; Yegorov, V. D.  
 ORG: Physics Institute im. P. N. Lebedev, AN SSSR, Moscow (Fizicheskii  
 institut AN SSSR)  
 TITLE: Energy of ionization by means of electrons in germanium and  
 silicon carbide crystals  
 SOURCE: Fizika tverdogo tela, v. 7, no. 12, 1965, 3702-3704  
 TOPIC TAGS: silicon carbide, germanium, ionization, electron bombard-  
 ment, forbidden band, excitation energy  
 ABSTRACT: The purpose of the investigation was to determine by means  
 of a new procedure the ionization energy under conditions where the  
 excitation is not confined to the surface region. It is shown briefly  
 that the latter circumstance results in certain errors. The ioniza-  
 tion energy was determined from the change in the voltage drop, and  
 consequently from the change in conductivity, resulting from irradi-  
 ating a crystal with electrons from a 150-keV accelerator. A formula

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L 15738-66

ACC NR: AP6000900

relating the voltage drop with the ionization energy is written under the assumption that the concentration of the nonequilibrium carriers varies linearly with the time after turning on the excitation, and that the current density of the incident electrons is sufficiently small and uniform over the entire surface of the sample. The measurements were made on n-type Ge and  $\alpha$ -SiC measuring 4 x 6 x 1 and 2 x 4 x 5 mm respectively. The ionization energies were found to be  $9.0 \pm 0.7$  and  $2.4 \pm 0.2$  eV for the silicon carbide and germanium respectively. In the case of silicon carbide, the results agree with the assumption that the ionization energy is approximately triple the width of the forbidden band. In the case of germanium the results agree with data obtained by x-ray and gamma-ray excitation, but are lower than the value obtained for alpha-particle excitation, probably because of recombination losses in the plasma inside the track. Authors thank B. M. Vul, E. L. Nolle, and G. N. Galkin for help with the work and a discussion of the results. Orig. art. has: 1 figure, 1 table, and 1 formula.

SUB CODE: 20/ SUBM DATE: 26Jul65/ ORIG REF: 007/ OTH REF: 002

Card

2/2

L 42100-66 EWT(1)/T IJP(c) AT

ACC NR: AP6003167

SOURCE CODE: UR/0030/65/007/012/078/0079

AUTHOR: Vavilov, V. S. (Doctor of physico-mathematical sciences)

ORG: none

79  
B

TITLE: International symposium on the recombination of nonequilibrium current carriers in semiconductors

SOURCE: AN SSSR. Vestnik, no. 12, 1965, 78-79

TOPIC TAGS: physics conference, semiconductor research, cadmium sulfide, semiconductor device, electron recombination, germanium semiconductor, transistor, crystal lattice vibration, electron beam, cadmium telluride

ABSTRACT: The International Symposium on the Recombination of Nonequilibrium Current Carriers in Semiconductors was held in Warsaw Poland from 27 June to 1 July 1965.

The Soviet delegation presented four conference papers. V. Ye. Lashkarev reported on the complex investigation of recombination processes in CdS type semiconductors. A report by S. G. Kalashnikov, N. G. Zhdanova and M. S. Kogan dealt with the recombination of hot electrons in Ge impurity centers. S. M. Ryvkin made a theoretical review of the possibility of electron transitions at which emitted (or absorbed) energy is imparted to both lattice vibration and free charge carriers (electrons and holes). A report by V. S. Vavilov, E. L. Nolle, and S. N. Maksimovskiy dealt with the spontaneous electron-beam-pumped CdTe.

SUB CODE: 20/ SUBM DATE: none

Card 1/1 af

... VAVILOV, V.S., doktor fiz.-matem.nauk

Symposium on the recombination of nonequilibrium current  
carriers in semiconductors held in Warsaw. Vest. AN SSSR  
35 no.12:78 D '65. (MIRA 19:1)

L 39727-66 EWP(t)/EWA(h)/EWT(x) JD/JG/GD-2

ACC NR: AP6007175

SOURCE CODE: UR/0188/66/000/001/0081/0084

AUTHORS: Vavilov, V. S.; Golovina, N. V.; Iferov, G. A.;  
Tulinov, A. P.; Chukichev, M. V.

ORG: NIIYaF MGU

TITLE: Use of semiconductor counters of the p-i-n type to study  
nuclear reactions<sub>4</sub>

SOURCE: Moscow. Universitet. Vestnik. Seriya III. Fizika,  
astronomiya, no. 1, 1966, 81-84

TOPIC TAGS: junction diode, semiconductor device, crystal counter,  
silicon, alpha particle reaction

ABSTRACT: The authors describe a procedure for preparing p-i-n  
junction counters. The procedure is based on the drift of lithium  
ions in silicon. The counters obtained in this manner were used to  
investigate nuclear reactions induced by  $\alpha$  particles accelerated to  
26 Mev at the cyclotron of NIIYaF MGU. Zone-melted silicon with  
resistivity 450 -- 800 ohm-cm was used as the initial material. Lith-

Card

1/2

UDC: 539.1.074

L 39727-66

ACC NR: AP6007175

ium was deposited on its surface by vacuum sputtering and allowed to diffuse at 450 -- 500C to a depth ~ 100  $\mu$ . The ion drift was produced in silicone oil at 120C and an inverse voltage of 300 V. The resolving power of the counters was determined by measuring the spectrum of  $\alpha$  particles from a  $\text{Cm}^{242}$  source, and was found to range from 0.9 -- 1.5%. The counters were used to investigate elastic and inelastic scattering of 26.3 Mev  $\alpha$  particles by carbon nuclei. The tests have shown that the excitation functions plotted at fixed angles exhibited as a rule sharply pronounced nonmonotonicity, probably due to the appearance of some individual levels or groups of levels in the compound nucleus. The experimental data obtained were used to construct the angular distributions at different energies of the incident particles. These were found to agree with theory at small angles and exhibited a regular tendency for an increase in the differential cross section at large angles. No agreement was observed at medium angles. The results agree with the calculations based on the adiabatic model only at small angles. The authors thank I. B. Teplov, P. Matyya, and V. A. Kozlov for help during the work. Orig. art. has: 6 figures.

SUB CODE: 20/ SUBM DATE: 19Sep64/ OTI REF: 004

Card *pk* 5 2/2

L 40050-66 ENT(1)/T IJF(c)-AT  
ACC NR: AP6022024

SOURCE CODE: UR/0120/66/000/003/0176/0179

AUTHOR: Vavilov, V. S.; Nolle, E. L.; Yegorov, V. D.; Golubev, G. P.; Mashtakov, V. S.  
ORG: Institute of Physics, AN SSSR, Moscow (Fizicheskii institut AN SSSR)

TITLE: Outfit for studying the recombination radiation of electron-excited  
semiconductors 47 B

SOURCE: Pribery i tekhnika eksperimenta, no. 3, 1966, 176-179

TOPIC TAGS: semiconductor research, recombination radiation

ABSTRACT: Connected with the outfits described by C. Benoit et al. (Physics of Semiconductors, Paris, Dunod, 1964), an improved outfit developed by the authors is capable of exciting semiconductors by 150-kev electron pulses that have a current density of 3 amp/cm<sup>2</sup>; pulse duration, 0.25--10  $\mu$ sec; repetition rate, up to 30 cps. Stimulated radiation of cadmium telluride was achieved in this outfit for the first time. An electron tube with a constant high voltage and a pulsed grid modulation is used for high-power electron excitation of semiconductors; a 20-section steatite tube has been actually used. A block diagram of the outfit, principal circuits of the pulse generator and synchronous detector, and the pulse shape of the electron beam are shown. A He cryostat permits studying the recombination radiation of semiconductors at temperatures down to 10K. "The authors wish to thank S. I. Vintovkin, V. S. Ivanov, and B. D. Kopylovskiy for their valuable advice connected with the development of the outfit." Orig. art. has: 4 figures. [03]

SUB CODE: 20, 09 / SUBM DATE: 25May65 / ORIG REF: 004 / OTH REF: 002

Card 1/1 *gd*

UDC: 539.293

L 24202-66 EWT(1)/T/EWA(h) IJP(c) AT  
ACC NR: AP6014611

SOURCE CODE: UR/0386/66/003/009/C361/0365

AUTHOR: Blinov, L. M.; Vavilov, V. S.; Ga'kin, G. N.

ORG: Physics Institute im. P. N. Lebedev, Academy of Sciences SSSR (Fizicheskiy institut Akademii nauk SSSR)

TITLE: Photo emf of p-n junction in a strongly excited semiconductor

SOURCE: Zhurnal eksperimental'noy i teoreticheskoy fiziki. Pis'ma v redaktsiyu. Prilozheniye, v. 3, no. 9, 1966, 361-365

TOPIC TAGS: silicon, pn junction, photo emf, ruby laser, laser application, electric potential, potential barrier

ABSTRACT: The authors investigated the variation of the photo<sup>2/</sup> emf with the radiation power incident on a silicon crystal with a p-n junction. The p-n junctions were obtained either by diffusion of phosphorus in p-type silicon or by bombarding p-type silicon with phosphorus, the latter junctions being shallower. The light source was a Q-switched ruby laser ( $\lambda = 0.69 \mu$ ). A set of filters calibrated at high and low radiation power made it possible to cover the light intensity range from  $10^{-1}$  to  $5 \times 10^8$  w/cm<sup>2</sup>. To check whether the photoemf depends on the duration of the pulse, some experiments were made with the laser without Q switching. The

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L 24202-66

ACC NR: AP6014611

measurements have shown that the emf tends to saturate with increasing light intensity, that the saturation of the photo emf extends over several orders of magnitude of the radiation power, and in no case does the limiting photo emf coincide with the theoretical value of the contact potential difference, as would be the case with the potential barrier of the p-n junction to be completely lifted. It is therefore concluded that the contact potential difference in silicon p-n junction cannot be determined by measuring the saturation photo emf. The authors thank Corresponding Member of AN SSSR B. M. Vul and V. D. Yegorov for various remarks, and also N. M. Borodina and V. V. Titov for supplying the samples of the silicon with p-n junction. Orig. art. has: 2 figures. [02]

SUB CODE: 20/ SUBM DATE: 07Mar66 ORIG REF: 001/ OTH REF: 003/ ATD PRESS:

4245

Card 2/2

BKG

L 25483-66 EWA(h)/EWT(1)/EWT(m)/T IJP(c) AT/JD/JG

ACC NR: AP6009683

SOURCE CODE: UR/0181/66/008/003/0908/0911

AUTHOR: Vul, B. M.; Vavilov, V. S.; Galkin, G. N.; Bobrova, Ye. A.

ORG: Physics Institute im. P. N. Lebedev, AN SSSR, Moscow (Fizicheskii Institut AN SSSR)

TITLE: Radiative recombination in gallium-arsenide diodes

SOURCE: Fizika tverdogo tela, v. 8, no. 3, 1966, 908-911

TOPIC TAGS: gallium arsenide, radiative recombination, pn junction, junction diode, recombination emission, forbidden band

ABSTRACT: To clarify the character of recombination processes corresponding to the particular emission band in GaAs (the short-wave band or one of the few long-wave bands), the authors investigated the dependence of the radiation intensity of each of the bands on the density of the current through a p-n junction. The samples tested were GaAs diodes in which the p-n junctions were obtained by diffusion of zinc in n-type material. The radiation was observed in a direction normal to the plane of the junction from the n-region side. Measurements were made of the emission spectrum of the investigated samples, of the dependence of the intensity of the emission of the individual bands on the injection current at various temperatures at high injection levels, and of the dependence of the internal quantum efficiency on the temperature. The results show that the short-wave band, with a quantum energy close to the width of the forbidden band, is connected at high injection levels with

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ACC NR: AP6009683

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a bimolecular recombination law; the long-wave band is connected with a monomolecular recombination law. It is concluded that the nonradiative recombination at high injection levels should also obey the bimolecular law. The authors thank Yu. V. Popov and A. I. Frimer for supplying important experimental data. Orig. art. has: 4 figures and 4 formulas.

SUB CODE: 20/ SUBM DATE: 27Jun65/ ORIG REF: 004/ ...I REF: 003

Card 2/2

137443-86 ERF(1)/ERF(6)/ERF(11)/ERF(12) JF/RR  
ACC NR: AP6015473 (A) SOURCE CODE: UR/0181/06/008/005/1522/1527

AUTHOR: Vavilov, V. S.; Golubev, G. P.; Konorova, Ye. A.; Nolle, E. L.; Sergiyenko, V. F.

ORG: Physics Institute im. T. N. Lebedev AN SSSR, Moscow (Fizicheskiy institut AN SSSR) 53

TITLE: Recombination radiation of diamonds during excitation by electrons 17

SOURCE: Fizika tverdogo tela, v. 8, no. 5, 1966, 1522-1527

TOPIC TAGS: recombination radiation, diamond, excitation spectrum, electron beam

ABSTRACT: The authors study the recombination radiation spectrum of a diamond near the fundamental absorption edge and in the visible region. A pulsed beam of 150 keV electrons was used for excitation. The pulse duration was variable from 1.3 to 12  $\mu$ sec with a prr of 10 cps. The current density in the beam could be raised to 2 a/cm<sup>2</sup>. The recombination radiation spectrum extended in the visible region from 580 to 320 m $\mu$ . Some specimens showed a narrow band with a maximum at 389 m $\mu$ . The radiation spectrum in the ultraviolet region consists of three bands with maxima at 235, 242.3, and 250 m $\mu$ . The integral intensity of the fundamental radiation band (maximum 235 m $\mu$ ) is only 0.5-1% of the integral radiation intensity in the visible region. It is assumed that the bands at 242.3 and 250 m $\mu$  are phonon repetitions of the band at 235 m $\mu$ .

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ACC NR: AP6015473

When the curve for this band is extended along the axis for phonon energy it appears asymmetric with a form approaching Maxwell distribution, which indicates that the radiation is due to recombination of free particles. The shape and position of the ultraviolet radiation bands, and the effect of excitation level and temperature on luminescence intensity show that luminescence is caused by annihilation of excitons with simultaneous radiation of phonons. Orig. art. has: 5 figures, 3 tables. [14]

SUB CODE: 20/

SUBM DATE: 21Oct65/

OTH REF: 006/ ATD PRESS: 5025

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L 29932-66 EWT(1)/EWT(m)/T/EWF(e)/EWP(t)/ETI LJP(c) AT/WH/ID  
 ACC NR: AP6018580 SOURCE CODE: UR/0181/66/008/06/1964/1965

AUTHOR: Vavilov, V. S.; Guseva, M. I.; Konorova, Ye. A.; Krasnopevtsev, V. V.;  
Sergiyenko, V. F.; Titov, V. V. 71  
 66  
 B

ORG: Physics Institute im. P. N. Lebedev, AN SSSR, Moscow (Fizicheskiy institut AN SSSR)

TITLE: Semiconductor diamonds<sup>2/</sup> obtained by ion bombardment<sup>2/</sup>

SOURCE: Fizika tverdogo tela, v. 8, no. 6, 1966, 1964-1965

TOPIC TAGS: semiconductor alloy, semiconductor crystal, semiconductor conductivity, diamond

ABSTRACT: An investigation was made of the dependence of electric conductivity on the temperature and concentration of the impurities introduced into a layer of diamond doped with lithium and boron by ion bombardment. Diamond doping was carried out in an ion-ray installation with a magnetic separation at a focusing angle of 180°. Lithium and boron ions with an energy of 40 kev were introduced into the natural face of the crystal or into the cleavage plane perpendicularly to the crystallographic directions [111] and [100]. The activation energy for lithium was  $(0.29 \pm 0.01)$  ev and for boron  $(0.25 \pm 0.01)$  ev. Lithium-doped diamond has an electron-type conductivity, while in boron-alloyed diamond the holes are the major charge carriers. Annealing of specimens at 600C for three hours in an argon atmosphere had virtually no effect on the activa- 27

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ACC NR: AP6018580

tion energy of electric conductivity; the general resistance of the doped layer increased somewhat only in the case of boron. The acceptor and donor levels appearing in the forbidden band as the result of radiative defects are deep and have only a slight effect on the activation energy. With an increasing concentration of lithium, the activation energy decreases in the range of high temperatures as well as in the range of lower temperatures. These rules apply to the impurity band, in which the concentration of lithium is about  $10^{20} \text{ cm}^{-3}$ . Ion bombardment makes it possible to obtain semiconducting layers of diamond whose electric conductivity can change by 5 to 10 orders, depending on the extent of doping. The energy level corresponding to the lithium admixture is separated by 0.29 eV from the bottom of the conductivity band, while the energy level of boron is 0.25 eV from the top of the valence band. The authors thank V. M. Gusev for collaboration in the work, V. A. Mizonova and N. A. Shuvalova for the preparation of specimens, Yu. Ye. Andreyev for participation in the measurements, and S. A. Shevchenko for supplying a device for determining the sign for the Hall coefficient. Orig. art. has: 2 figures and 1 table. [JA]

SUB CODE: 20/ SUBM DATE: 08Jan66/ OTH REF: 004/ ATD PRESS: 5011

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L 42123-66 E/T(1)/E.T(m)/T/ESP(t)/ETI IJP(c) JD/GG/AT

ACC NR: AP6024453

SOURCE CODE: UR/0181/66/008/007/1981/1984

AUTHOR: Akimchikov, I.E.; Vavilov, V.S.; Plotnikov, A.P.

ORIGIN: Physics Institute im. P. N. Lebedev, AN SSSR, Moscow (Fizicheskii institut AN SSSR)

TITLE: Photoconductivity spectra of oxygen-alloyed germanium crystals irradiated with fast electrons

SOURCE: Fizika tverdogo tela, v. 8, no. 7, 1966, 1981-1984

TOPIC TAGS: photoconductivity, spectrum, germanium single crystal, fast electron, electron irradiation, crystal impurity, oxygen impurity

ABSTRACT: In addition to electrically active impurities, germanium crystals also contain neutral impurities, specifically oxygen, the concentration of which in normal crystals may reach  $10^{16} \text{cm}^{-3}$ . It is not excluded that associations of point-contact defects with oxygen atoms may appear in Ge crystals upon irradiation. The authors were unable to determine the oxygen concentration in normal crystals in an absorption band at a wavelength of  $11.6 \mu$ . At their request, the Semiconductor Department of MGU (Kafedra poluprovodnikov MGU) grew an oxygen-alloyed germanium crystal. The crystal was subjected to dilation in an oxygen atmosphere with noncontrolled pressure. The single crystal obtained has n-type electroconductivity and a resistivity from 2 to 10 ohm-cm. On the basis of the investigations performed, the authors conclude that the

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